REMARKS

This amendment, submitted in response to the Office Action dated May 10, 2002, is believed to be fully responsive to each point of rejection raised therein. Accordingly, favorable reconsideration on the merits is respectfully requested.

As a preliminary matter, the Examiner has objected to the specification, claims and drawings for containing informalities. The specification and claims have been amended as set forth above. Proposed drawings corrections are being filed concurrently herewith.

Turning to the merits of the Office Action, claims 1-8, 31-36 and 59-61 are pending in the application. Claims 9-30, 37-58 have been cancelled and new claims 59-61 have been added. Claims 1-8 have been rejected under 35 U.S.C. § 103 as being unpatentable over Van den Bogaert (research Disclosure 34264) in view of Tsuji et al. (U.S.P. 5,196,702, hereafter "Tsuji"). Claims 31 and 34 have been rejected under 35 U.S.C. § 103 as being unpatentable over Van den Bogaert in view of Tsuji and further in view of Hunter et al (U.S.P. 6,192,105, hereafter "Hunter"). Applicant submits the following arguments in traversal of the prior art rejections.

Applicant's invention relates to an apparatus and a method for efficiently reading out images stored to a stimulable phosphor. Known techniques require large and fragile photoconductor components and also are susceptible to large dark currents which adversely affect the signal to noise ratio.

The present invention, as illustrated in exemplary form in Fig. 3, obviates the above deficiencies. When a radiation image signal stored to a stimulable phosphor 12 is be read out, a high electric field not lower than 10^6 V/cm is applied between electrode elements 26a and 22a. As a result, an avalanche amplification effect is generated, whereby generation of positive and

negative charges in the photoconductive material 23 increases significantly. The quantum effeciciency of the phosphor layer 12 is generally low and the stimulated emissions L4 are weak. Accordingly the amount of charges generated by exposure to the stimulated emission is small. However, with the avalanche amplification effect during the image detection, generation of the charges becomes multiplied and a larger S/N ratio can be produced.

Turning to the cited art, Van den Bogaert relates generally to a radiation read out system using a stimulable phosphor disposed adjacent to a photoconductive read out structure.

Tsuji relates to a radiation imaging and read out apparatus having a simplified structure. In relevant part, Tsuji describes recording a radiation image to a first photoconductor. See Fig. 12, element 1201. During image recording, the first photoconductive layer blocks the incident fluorescent light, attains a sufficient quantum efficiency when operated in the avalanche region, and detects X-rays transmitted through the fluorescent element 1120 so that the signal charges can be increased. Col. 24, lines 15-22. The read out apparatus is described at cols. 27-28 and is illustrated in Fig. 14. During read out, the fluorescent detector and the x-ray detector have no relation to the reading of the image. Col. 27, lines 50-55. Significantly, during read-out, no electric voltage is applied to the electrodes to create an avalanche effect. Rather, current output from an electrode 1405 is subjected to current voltage conversion and sent to a downstream processor. Col. 28, lines 3-14. It appears that key feature of Tsuji is to maintain an electric field in the second photoconductor at the end of a reading operation. Col. 10, line 68 to col. 11, line 2. At the conclusion of reading, an optical source must irradiate the second photoconductor with a reading light to create an electric field of the second photoconductor that is substantially flat.

Hunter relates to an apparatus and a method for calibrating the automatic exposure control of an x-ray imaging system. Fig. 7 of Hunter illustrates a plurality of detectors that mimic the detection of a converting medium. These detectors may detect light emitted from various screens, and may comprise a charge sensitive amplifier or an ion chamber that directly measures X-rays. Col. 11, line 15 to col. 12, line 12. Referring to Fig. 1, the operation of the calibrator includes passing x-rays through a patient 4 and through a grid that absorbs any scattered X-rays. Upon passing through the grid 5, the x-rays interact with an automatic exposure control device 6 which weakly absorbs x-rays while not interfering with the X-ray image. The automatic exposure control device 6 generates a signal V_{AEC} that indicates the x-rays sensed by the automatic exposure control device. A target level for the exposure amount T_{AEC} provides a reference for comparison with V_{AEC} to determine whether sufficient X-ray exposure has been reached. Col. 6, lines 3-45.

The Examiner contends that the combination of Van den Bogaert and Tsuji teaches or suggests each feature of independent claim 1. The Examiner correctly concedes that Van den Bogaert does not teach providing an avalanche effect in the photoconductive layer and cites Tsuji to make up for this deficiency. Applicant would argue that the rejection is not supported for at least the following two reasons.

First, claim 1 describes that electric charges generated in the photoconductive material upon exposure to stimulated emission occurs while applying an electric field to the photoconductive material during an image detection operation. By contrast, during the read out of an image in Tsuji, there is no indication that any electric field is applied to the photoconductive layer. For instance, Fig. 14 illustrates the read out structure but shows no

application of a potential field across the photosensor structure. Rather, in Tsuji, the application of an avalanche effect in Tsuji occurs during the recording of the material. Col. 24, lines 15-22. Applicant would submit that Tsuji suggests that the provision of the avalanche effect during the recording to the photoconductive layer has no bearing on providing such an avalanche effect during the image detection from the photoconductive layer. See col. 27, lines 53-54.

Second, Applicant would argue that modifying Tsuji to include the avalanche effect in the reading apparatus would contradict a principle of operation of the reference. Tsuji seeks to maintain a potential field across the second photoconductor to maintain that element in an equilibrium condition so that it exists in a prepared state upon the next writing operation. In this way, Tsuji eliminates the need for additional switches to restore the equilibrium condition between successive recordings and readings images. Applicant would submit that provision of an avalanche effect in the read out stage would deplete the charge carriers in the second photoconductor to such an extent that an additional set up and switching time would be required to restore the equilibrium prior to the next recording and reading operation. Applicant would submit that completely contradicts the objects of the reference, and that the reference thus teaches away from the features of claim 1.

Because claim 5 includes features similar to that discussed above for claim 1, claim 5 is also patentable for at least the reasons set forth above. Claims 2-4 and 6-8 are patentable based on their dependency.

With further regard to claims 4 and 8, these claims describe suppression of the electric field applied to the photoconductive material. The Examiner contends that the suppression of the

fluctuation is implicated by maintaining a constant quantum efficiency in Tsuji. Applicant would submit that the Examiner's rationale is not supported by the reference. In fact, it appears that Tsuji expressly contradicts the importance of maintaining a constant quantum efficiency. This is because during the recording phase, the avalanche effect becomes augmented by irradiation of X-rays. See col. 23, lines 14-20 and col. 24, lines 15-22. Due to an intervening irradiated object, the irradiation of the X-rays onto the photoconductor would not be uniform across the photoconductor. Therefore, this contradicts the Examiner's assumption regarding the need to maintain a constant quantum efficiency. Since the varying quantum efficiency due to x-ray irradiation poses no concern during application of the avalanche effect, there is no motivation to provide suppress electric field fluctuations that may affect the quantum efficiency. The Examiner has failed to offer a sufficient reason as to why the suppression aspects of claims 4 and 8 are taught in the art.

With regard to claims 31 and 34, the Examiner maintains that the combination of Van den Bogaert, Tsuji and Hunter teaches each feature of these claims. The Examiner correctly concedes that the primary combination does not teach a preliminary read-out signal bearing image information thereon, but cites Hunter to make up for this deficiency. The Examiner specifically cites the automatic exposure control device for teaching this feature. However, the automatic exposure device determines X-ray levels and does not interfere with the creation of image-bearing information. Accordingly, the automatic exposure control does not create a signal that bears any image information as the Examiner contends. See col. 6, lines 14-17. The alternative embodiment of Fig. 7 operates in a similar manner as that described in col. 6 and

therefore, the Examiner's reliance on Fig. 7 for teaching the preliminary read-out as described by claims 31 and 34 does not support the rejection.

Applicant has added claims 59-61 to describe features of the invention more particularly.

In view of the above, Applicant submits that claims 1-8, 31, 34 and 59-61 are in condition for allowance. Because claims 31 and 34 have been deemed generic, the non-elected claims should be rejoined and allowed in the present application. Therefore it is respectfully requested that the subject application be passed to issue at the earliest possible time. The Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

Respectfully submitted,

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APPENDIX

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

The specification is changed as follows:

Page 4, second paragraph, delete and insert the following:

(4) The photomultiplier comprises a complicated multistage [diode] dynode, and accordingly it is difficult to make a line sensor which is large in width, e.g., 17 inches, and is as small as about 100μm in picture element size.

Page 5, paragraph bridging page 6, delete and insert the following:

However, use of a line sensor formed of the materials described above gives rise to the following problems. That is, though it is advantageous that the solid photoelectric convertor element itself has electron multiplying function since the stimulated emission is very weak, any one of the line sensors formed of the materials described above except the Si photodiode exhibits no avalanche amplification effect as the electron multiplying function. On the other hand, the line sensor of the Si photodiode is very low (substantially zero) in quantum efficiency (sensitivity) to light in an ultraviolet to blue region and is high in quantum efficiency (sensitivity) to light in a red region, which results in a poor blue/red sensitivity ratio. Further since being large in dark current, the line sensor of the Si photodiode is not sufficient to detect weak stimulated emission in a blue region, and accordingly, an obtained image is very low in S/N ratio and in quality. Further, when a long line sensor such as of 17 inches is made of Si photodiode, the line sensor becomes very expensive. Further since the stimulated emission is very weak, it is necessary for the photoconductive material layer to be very high in dark

resistance. However, the photoconductive material described above are all low in dark resistance and accordingly read-out must be effected with a relatively high electric field applied to the photoconductive material layer, which increases the dark current and makes [is] it difficult to obtain a high S/N ratio.

Page 21, first paragraph, delete and insert the following:

Further since a-Se hardly has sensitivity to light in a wavelength range not shorter than 600nm and almost wholly transmits such light, a-Se is large in the ratio of the sensitivity to the stimulated emission (near 400nm) to that to the stimulating light (600 to 700nm). For example, in a state where no avalanche amplification effect is obtained, the ratio of the sensitivity to blue light (470nm) to that to red light (680nm) is about 3.5 [figures] when the thickness of the a-Se layer is 10μm. As the thickness of the a-Se layer is smaller, the blue/red sensitivity ratio increases and when an avalanche amplification effect is available, the blue/red sensitivity ratio further increases. Accordingly, use of a stimulating light cut filter is basically unnecessary, and by projecting stimulating light not shorter than 600nm in wavelength through a photoconductive material layer of a-Se, stimulated emission emitted from the surface of the stimulable phosphor layer can be effectively detected by the photoconductive material layer, whereby an image at high quality can be obtained. Further, since a-Se is very high in dark resistance as compared with a Si avalanche photodiode and the like, a high S/N ratio can be obtained.

Page 37, paragraph bridging page 38, delete and insert the following:

Further since a-Se hardly has sensitivity to light in a wavelength range not shorter than 600nm and almost wholly transmits such light, a-Se is large in the ratio of the sensitivity to the

stimulated emission (near 400nm) to that to the stimulating light (600 to 700nm). For example, in a state where no avalanche amplification effect is obtained, the ratio of the sensitivity to blue light (470nm) to that to red light (680nm) is about 3.5 [figures] when the thickness of the a-Se layer is 10 μm. As the thickness of the a-Se layer is smaller, the blue/red sensitivity ratio increases and when an avalanche amplification effect is available, the blue/red sensitivity ratio further increases. Accordingly, use of a stimulating light cut filter is basically unnecessary, and by projecting stimulating light not shorter than 600nm in wavelength through a photoconductive material layer of a-Se, stimulated emission emitted from the surface of the stimulable phosphor layer can be effectively detected by the photoconductive material layer, whereby an image at high quality can be obtained. Further, since a-Se is very high in dark resistance as compared with a Si avalanche photodiode and the like, a high S/N ratio can be obtained.

Page 61, paragraph bridging page 62, delete and insert the following:

Further since a-Se hardly has sensitivity to light in a wavelength range not shorter than 600nm and almost wholly transmits such light, a-Se is large in the ratio of the sensitivity to the stimulated emission (near 400nm) to that to the stimulating light (600 to 700nm). For example, in a state where no avalanche amplification effect is obtained, the ratio of the sensitivity to blue light (470nm) to that to red light (680nm) is about 3.5 [figures] when the thickness of the a-Se layer is 10 μm. As the thickness of the a-Se layer is smaller, the blue/red sensitivity ratio increases and when an avalanche amplification effect is available, the blue/red sensitivity ratio further increases. Accordingly, use of a stimulating light cut filter is basically unnecessary, and by projecting stimulating light not shorter than 600nm in wavelength through a photoconductive material layer of a-Se, stimulated emission emitted from the surface of the stimulable phosphor

layer can be effectively detected by the photoconductive material layer, whereby an image at high quality can be obtained. Further, since a-Se is very high in dark resistance as compared with a Si avalanche photodiode and the like, a high S/N ratio can be obtained.

Page 69, first full paragraph and paragraph bridging page 70, delete and insert the following:

Further when the photoconductive material layer 23 is of a-Se, the photoconductive material layer 23 is transparent to the red stimulating light and accordingly, the stimulating light [23] L3 can be projected onto the stimulable phosphor layer 12 through the photoconductive material layer 23.

The electrode elements 22a of the first stripe electrode 22 extend in substantially perpendicular to the electrode elements 26a of the second strip electrode 26. The same number of electrode elements 22a as the number of picture elements in the direction of the array of the electrode elements 22a are provided and the same number of electrode elements 26a as the number of picture elements in the direction of the array of the electrode elements [22a] 26a are provided. That is, the pitch of the electrode elements determines the pitch of the picture elements. When the electrode 22 of the first electrode layer 21 is thus divided by picture element pitch so that each electrode element 22a is in one-to-one correspondence with one picture element, the area of each electrode element 22a is greatly reduced, where the dark current and the output capacity are suppressed. Accordingly, dark current noise and/or capacity noise are reduced and the S/N ratio of the image can be improved.

Page 74, first full paragraph, delete and insert the following:

The electric voltage imparting means 85 selectively closes the switch elements 84a in response to movement of the stimulating light L3 under the control of a control means (not shown) so that the electrode element 26a corresponding to the line just exposed to the stimulating light L3 is electrically connected to the negative pole of the power source 82. With this arrangement, an electric voltage is imparted between the electrode element 26a corresponding to the line and all the electrode elements [22] 22a from the power source 82 by way of the switch 83 and an imaginary short circuit of the operational amplifier 81a, whereby an electric field is applied to the part of the photoconductive material layer 23 between the electrode elements 26a and 22a corresponding to the line. The system may be arranged so that an electric voltage is imparted between several electrode elements 26a including the electrode element 26a corresponding to the line and all the electrode elements 22a.

Page 79, paragraph bridging page 80, delete and insert the following:

Further since the major component of the photoconductive material layer 23 is a-Se, the ratio of the sensitivity to the stimulated emission (near 400nm) to that to the stimulating light (600 to 700nm) can be sufficiently large. For example, in a state where no avalanche amplification effect is obtained, the ratio of the sensitivity to blue light (470nm) to that to red light (680nm) is about 3.5 [figures] when the thickness of the a-Se layer is 10μm. This value is very large as compared with that (ratio of 2 [figures]) when a photomultiplier is employed as the photoelectric convertor means. As the thickness of the a-Se layer is smaller, the sensitivity to red light lowers and the blue/red sensitivity ratio increases and when an avalanche amplification effect is available, the blue/red sensitivity ratio further increases. Further, since Si is high in sensitivity to red light and low in sensitivity to blue light, Si is not suitable when the stimulated

emission is blue.

Page 85, last paragraph, delete and insert the following:

The radiation image detecting sheet 2 of this embodiment differs from the radiation image detecting sheet 1 of the first embodiment in that another (second) image read-out portion 30 is provided on the base 11 of the radiation image detecting sheet 1 of the first embodiment. That is, the second image read-out portion 30 comprises a first electrode layer 31 (equivalent to the first electrode layer 21 of the first image read-out portion 20), a photoconductive material layer 33 (equivalent to the photoconductive material layer 23 of the first image read-out portion 20), and a second electrode layer 35, including electrode portion 36a, (equivalent to the second electrode layer 25 of the first image read-out portion 20) superposed one on another in this order, and is superposed on the base 11 with the second electrode layer 35 facing the base 11. The base 11 is transparent to the stimulated emission L4. The second image read-out portion 30 may be superposed on the base 11 with the first electrode layer 31 having electrode portions 31a, 32a facing the base 11.

Page 100, paragraph bridging pages 101 and 102, delete and insert the following:

As shown in Figures 13A and 13B, the solid image sensor 223 comprises a glass substrate 226, a pair of long [flat] electrodes 223a and 223b and a long photoconductive material layer 223c sandwiched between the [flat] electrodes 223a and 223b. The electrode pairs may comprise flat electrodes. The photoconductive material layer 223c exhibits conductivity upon exposure to the stimulated emission L4 which impinges upon the photoconductive material layer 223c through the glass substrate 226. The solid image sensor 223 functions as a zero-dimensional sensor though large in length. The length of the

photoconductive material layer 223c is substantially the same as the dimension of the stimulable phosphor sheet 211 in the main scanning direction. The width of the photoconductive material layer (a-Se photoconductive film) 223c should be sufficiently smaller than the size of the stimulable phosphor sheet 211. For example, when the size of the stimulable phosphor sheet 211 is 430mmx430mm, the width of the photoconductive material layer 223c should be not larger than 50mm. When the area of the photoconductive material layer 223c is small, generation of an excessive dark current can be avoided and load capacity is reduced, whereby the S/N ratio can be improved as compared with when the radiation image detecting sheet 1, where the stimulable phosphor layer 12 and the photoconductive material layer 23 are of substantially the same area, is employed. A stimulating light cut filter 225 is disposed on the light inlet side of the glass substrate 226 (the side of the glass substrate 226 remote from the flat electrode 223a) and the side surface of the glass substrate 226 and the stimulating light cut filter 225 is covered with a light-shielding member 227. Since the photoconductive material layer 223c is low in sensitivity to the red stimulating light not shorter than 600nm as described above, the stimulating light cut filter 225 may be thinner as compared with when a photomultiplier is employed. The [flat] electrode 223a through which the stimulated emission L4 enters the photoconductive material layer 223c is made of a transparent conductive film such as an ITO film so that the stimulated emission L4 can impinge upon the photoconductive material layer 223c. As in the embodiment shown in Figures 11A and 11B, the photoconductive material layer 223c includes a-Se as the major component and the thickness of the photoconductive material layer 223c is preferably not smaller than 1μm and not larger than 100μm, and more preferably not smaller than 10μm and not larger than 50μm. The potential gradient in the photoconductive material layer 223c is set not lower than 10^6V/cm so that an avalanche amplification effect is

generated in the photoconductive material layer 223c. The solid image sensor 223 may be formed to have a cylindrical light inlet end face as shown in Figure 13B.

Page 115, first and second paragraphs, delete and insert the following:

Figure 23 shows a circuit for reading out the electric charges from the solid image sensor 223 and obtaining an image signal. As shown in Figure 23, the circuit comprises a current detecting circuit 80 connected to the solid image sensor 223, an A/D converter 86, a data correction section 87 and a ROM table 88. The circuit further comprises a read-out control circuit 300 connected between the current detecting circuit 80 and the A/D converter 86. The read-out control circuit 300 is for obtaining an image signal for one picture element by adding a plurality of output signals from the detecting amplifiers 81 which receive stimulated emission from the picture element while switching the output signals in response to scanning of the stimulating light [L] <u>L3</u>.

The current detecting circuit 80 is provided with a detecting amplifier 81 of a charge amplifier system comprising an operational amplifier 81a, an integrating capacitor 81b and switch 81c. The current detecting amplifier 81 detects an electric current generated when electric charges generated upon exposure of the photoconductive material layer [212] <u>223c</u> to stimulated emission L4 emitted from the stimulable phosphor layer 212 are read out and reads out an image signal representing radiation energy stored on the stimulable phosphor layer 212 <u>disposed on a substrate 213</u>.

Page 116, last paragraph, delete and insert the following:

Further, the current detecting circuit 80 is provided with an electric voltage imparting

means 85 which comprises a power source 82 and a switch 83 and imparts a predetermined electric voltage between the electrodes 223a and 223b of the solid image sensor 223, thereby applying an electric field to the photoconductive material layer [223] <u>223c</u> The positive pole of the power source 82 is connected to non-inversion input terminals (+) of the respective operational amplifiers 81a by way of the switch 83. The voltage of the power source 82 is set so that the potential gradient in the photoconductive material layer 223c becomes not lower than 10^6V/cm and an avalanche amplification effect is generated in the photoconductive material layer 223c.

Page 118, last paragraph bridging page 119, delete and insert the following:

Further since a high electric field not lower than 10^6V/cm has been applied between the electrode elements [22a] <u>223a</u> and [26a] <u>223b</u> corresponding to the read-out line and an avalanche amplification effect is generated, whereby generation of positive and negative charges in the photoconductive material layer 223c sharply increases. The quantum efficiency of the stimulable phosphor layer 212 is low and the stimulated emission L4 from the stimulable phosphor layer 212 is weak. Accordingly, the amount of charges (the number of signal photons) generated by exposure to the stimulated emission is small. However, by virtue of the avalanche amplification effect, generation of the charges is multiplied and a sufficiently strong signal can be obtained, whereby the S/N ratio can be increased.

Page 120, second paragraph, delete and insert the following:

Further since the major component of the photoconductive material layer 223c is a-Se, the ratio of the sensitivity to the stimulated emission (near 400nm) to that to the stimulating

light (600 to 700nm) can be sufficiently large. For example, in a state where no avalanche amplification effect is obtained, the ratio of the sensitivity to blue light (470nm) to that to red light (680nm) is about 35 [figures] when the thickness of the a-Se layer is 10μm. This value is very large as compared with that (<u>ratio of</u> 2 [figures]) when a photomultiplier is employed as the photoelectric convertor means. As the thickness of the a-Se layer is smaller, the sensitivity to red light lowers and the blue/red sensitivity ratio increases and when an avalanche amplification effect is available, the blue/red sensitivity ratio further increases.

Page 124, third paragraph, delete and inert the following:

Figures 26A to 26C show the solid image sensor employed in this embodiment. As shown in Figures 26A to 26C, the electrodes 223a and 223b are divided in the main scanning direction in the same manner into a plurality of elements so that each element of one of the electrode is opposed to one of the elements of the other electrode with the photoconductive material layer [223s] <u>223c</u> intervening therebetween. With this arrangement, a plurality of photoelectric conversion segments which function independently of each other are formed.

<u>**IN THE CLAIMS**</u>:

Claims 9-30 and 37-58 are cancelled.

The claims are amended as follows:

5 (Amended). An image read-out system comprising

a stimulating light source which emits stimulating light in a wavelength range of not shorter than 600nm,

a stimulating light scanning means which causes the stimulating light emitted from the

stimulating light source to scan a stimulable phosphor sheet having a layer of stimulable phosphor which emits stimulated emission in a wavelength range of not longer than 500nm in proportion to the stored energy of radiation upon exposure to the stimulating light,

a solid image sensor having a photoconductive material layer the major component of which is a-Se and which exhibits electric conductivity upon exposure to the stimulated emission from the stimulable phosphor sheet,

an electric voltage imparting means which imparts an electric voltage to the photoconductive material layer of the solid image sensor to apply such an electric field as to generate an avalanche amplification effect in the photoconductive material layer, and

an image signal obtaining means which detects electric charges generated in the photoconductive material layer of the solid image sensor when the stimulable phosphor sheet is exposed to the stimulating light and stimulated emission emitted from the stimulable phosphor sheet impinges upon the photoconductive material with an electric voltage imparted to the photoconductive material layer by the electric voltage [application] <u>imparting</u> means to apply [such an] <u>said</u> electric field as to generate [an] <u>said</u> avalanche amplification effect in the photoconductive material layer, and detects an image signal representing an image stored on the stimulable phosphor sheet.

Claims 59-61 are added.